Atomic-Level Design of Palladium Alloys: Decoding the Mechanisms for High-Performance Semiconductor Test Materials

Dr. Jonas Fecher - E-Mail: j.fecher@sickert-hafner.de **– SWTest Conference June 8-10 2026, Carlsbad CA**

The challenge

- Semiconductor test materials require high strength and conductivity, which are conflicting properties
- Achieving this balance through alloy design remains complex and typically empirical
- Understanding how microstructure governs properties is key to moving from trial-and-error towards targeted design

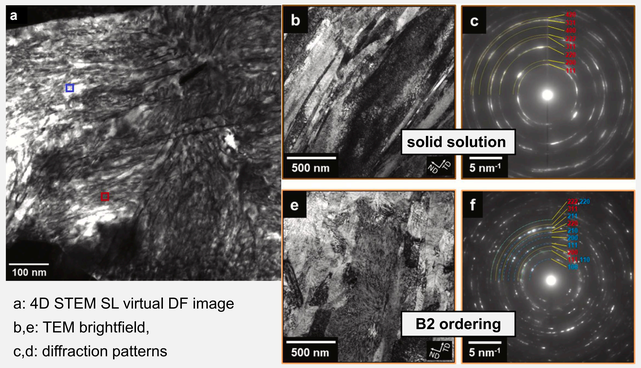
The approach

Multiscale characterization of the microstucture by

- 4D STEM
- Transmission electron microscopy
- Atomic-scale EDX mapping
- Synchrotron measurements

Microstructural mapping

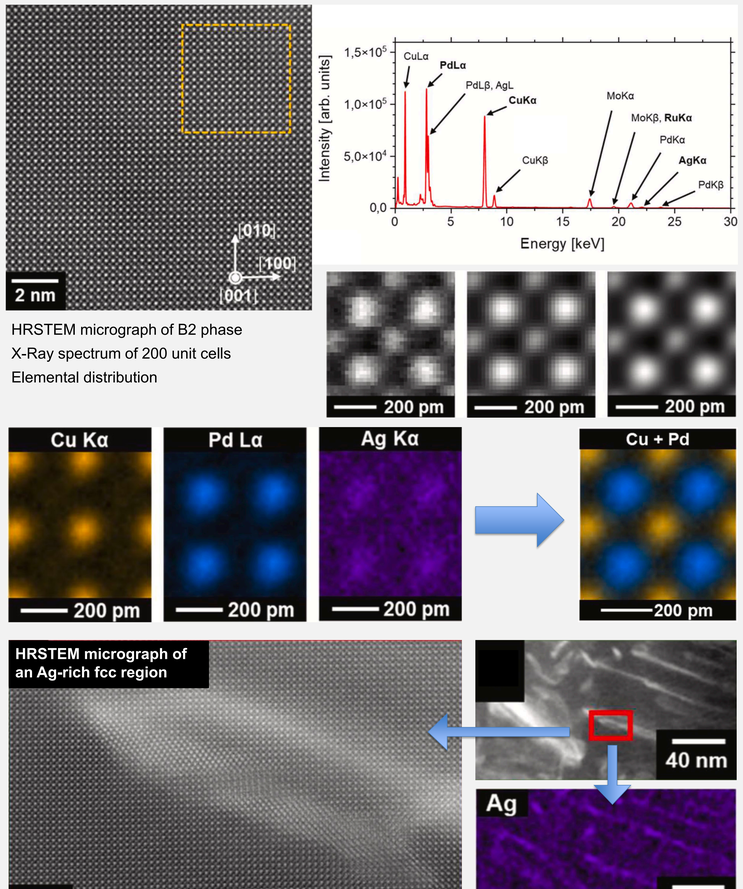
- TEM shows that the solid-solution state is dominated by fcc reflections, whereas the heat-treated state exhibits additional reflections consistent with B2 ordering
- 4D-STEM confirms that the B2 phase is finely and homogeneously distributed throughout the grain structure



a: 4D STEM SL virtual DF image
b,e: TEM brightfield,
c,d: diffraction patterns

Atomic scale picture – local ordering at atomic level

- High-resolution STEM and atomic-scale EDXS reveal sublattice occupation within the ordered phase
- Cu and Pd occupy distinct columns
- In the remaining fcc regions, Ag is locally enriched



HRSTEM micrograph of B2 phase
X-Ray spectrum of 200 unit cells
Elemental distribution

Property relevance – why structure matters

- The observed microstructural arrangement provides a basis for the improved hardness and electrical conductivity observed for the annealed state
- The performance is linked to the distribution of ordered and residual phases, not to a single bulk composition parameter
- Chemistry has significant impact on formation and stability of ordered phases
- Thermal treatment and deformation influence the formation of phases

Transferable framework

- The main insight is transferable: multiscale microscopy and synchrotron analysis can serve as a general roadmap for identifying the structural levers that control properties in ordered alloy systems
- This framework can be applied to other alloy systems where phase ordering and coherent phases govern performance
- Combined with our S-Tec manufacturing process, these insights support the development of tailored semiconductor test materials

Conclusion

Multiscale characterization reveals the microstructural map behind ordering-driven property improvement and identifies the key structural features associated with performance enhancements.

Combined with the S-Tec manufacturing process, these insights provide a practical route to tailor properties and material quality for application-specific requirements.

References

- M. Kuglstatter, N. Karpstein, B. Apeleo Zubiri, J. Fecher, E. Spiecker, H. W. Höppel, M. Göken, Microstructural evolution and B2 ordering in a new CuPdAgRu alloy. Scripta Materialia 272 (2026) 117053
- L.A. Lumper, J. Fecher, A. Stark and V. Maier-Kiener (2024), Investigation of Phase Transformations and Ordering Mechanisms in a Pd–Cu–Ag–Ru Alloy. Adv. Eng. Mater. 2400255.
- T. Happ, Revolutionizing Semiconductor Wafer Testing: A Breakthrough in Ultra-Precise High-Performance Foil Material. SWTest Conference 2025, Carlsbad CA